Tectonics

INTRODUCTION TO A SPECIAL SECTION
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Special Section:
Orogenic cycles: from field observations to global geodynamics

Key Points:
- This special section of *Tectonics* commemorates Associate Professor Marco Beltrando's early passing in December 2015
- This introduction explains the significance of Marco's research
- It also introduces and summaries all papers in the volume and indicates how they are linked

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Introduction to "Orogenic Cycles: From Field Observations to Global Geodynamics"

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Abstract This Special Section of *Tectonics*, entitled "Orogenic Cycles: From Field Observations to Global Geodynamics," has been compiled in commemoration of our friend and colleague Dr. Marco Beltrando, who tragically passed away in a mountain accident on 8 December 2015.

Dr. Beltrando was a dynamic and inspired young researcher, who had been awarded undergraduate and Master's degrees from Università di Tornio and Utrecht University in 2002 and a PhD by the Australian National University in 2007. Subsequently, he was a postdoctoral researcher at Université de Strasbourg and CNR Torino (2008–2011) and Università di Torino (2012–2014). In early December 2015, he was awarded a tenure track position for Associate Professor at the latter institution.

During his short, but influential research career, Dr. Beltrando led efforts to understand the complex geodynamics of the Western European Alps. His work involved a combination of outcrop-scale structural geology and geochronology, and he made a particularly important contribution to tectonic research by investigating how hyperextended rifted margins affect orogenic cycles. These studies were focused in the Canavese, Ivrea, and Santa Lucia zones, where he sought evidence that high-temperature metamorphism, and telescoping of metamorphic isograds affected the lower crust during the Triassic-Jurassic rifting. This volume provides an opportunity to commemorate his scientific contributions to our field and provides a basis for future investigations inspired by his insight.

Dr. Marco Beltrando (right). Photo credit: Gianreto Manatschal.

1. Orogenic Cycles

Orogens do not evolve in a continuum manner. Instead, their evolution is characterized by episodes of intense contractional deformation intermitted by periods of tectonic quiescence. The mechanics, rates, and drivers of such switches in tectonic mode have attracted substantial research at all scales, ranging from microstructural investigation of distinct shear zones to lithospheric-scale geophysical examination. The underpinning processes are still debated but can potentially be unraveled by cooperative consideration of emerging high-resolution structural, metamorphic, magmatic, geochronologic, and thermochronologic data.

This special volume addresses the topic of orogenic cycles based on observations made within the Western European Alps and the Mediterranean (part A) and comparable orogens worldwide (part B). It comprises a series of cutting-edge contributions that address three main topics: (i) the geologic evidence associated with orogenic cycles, (ii) the geodynamic processes governing orogenic cycles, and (iii) the implications of orogenic cycles to global tectonics. The studies described herein range from descriptions of field structural geology and geochronology/thermochronology, to plate kinematic reconstructions, and 3-D modeling and visualization. This combination of research methods and scales was an integral element of the research Dr. Beltrando was engaged in.

Many papers included in the volume build on presentations at the following commemorative conference sessions:

1. EGU General Assembly, Vienna, April 2016: Session TS6.2/GD6.6/SM6.16: *The Alps and European Alpine-type orogens: a multidisciplinary vision*
2. Italian Geological Society Annual Meeting, Naples, Sept. 2016: Session: P6 - *Geodynamics and Paleogeography of Tethyan belts: from convergence to exhumation*.
3. AGU Fall Meeting Dec. 2015 session T53C: *Rifts and Passive Margins: Tectonics, Dynamics, Processes V*

In summary, the scientific contributions within this volume are as follows.

1.1. Part A: Orogenic Cycles in the Western European Alps and Mediterranean

1.1.1. Geological Evidence Associated With Orogenic Cycles

Using zircon U-Pb dating, Langone et al. (https://doi.org/10.1002/2017TC004638) show that large-scale, lower crustal high-temperature shear zones in the Ivrea-Verbano Zone (N-Italy) are late Triassic to early Jurassic and formed coevally at different crustal levels during Mesozoic rifting.

Bergomi et al. (https://doi.org/10.1002/2017TC004621) use U-Pb dating to provide the first compelling evidence of Late Devonian orogenic magmatism in the European Alps. This result has major implications for the understanding of the Paleozoic paleogeographic and tectonic evolution of this area and its control on the subsequent Alpine orogenic evolution.

Valera et al. (https://doi.org/10.1002/2016TC004414) demonstrate that tectonic deformation rather than diaprism and/or gravitational processes, resulted in the deformation of evaporites at the present topographic front of the Guadalquivir Accretionary Complex (Betic-Rif orogen).

1.1.2. Geodynamic Processes Governing Orogenic Cycles

Based on low-T thermochronologic (Zr-FT) and petrological study of samples from the Calizzano Massif (Prepiedmont-Briançonnais Domain, Ligurian Alps) Decarlis et al. (https://doi.org/10.1002/2017TC004634) provide new evidence of high thermal gradients in the near-surface during the initiation of seafloor spreading.

Decarlis et al. (https://doi.org/10.1002/2017TC004561) review the Jurassic passive margin successions in the Western Alps. Based on this review they suggest an upper plate detachment model for the southern Adria rifted margin.

Favaro et al. (https://doi.org/10.1002/2016TC004448) propose a model of formation of the Tauern Window due to the motion to the north of the Adriatic indenter including coeval doming and orogen-parallel stretching in the Miocene. The eastern and western terminations of the window experienced different patterns of shortening and stretching.

Marroni et al. (https://doi.org/10.1002/2017TC004627) present a revised model of the precollisional evolution of the Apennines through analyses of stratigraphy and sedimentology of the Adria and Europen margins.

Milia et al. (https://doi.org/10.1002/2017TC004571) propose a new interpretation of the evolution of the Pliocene-Quaternary orogenic cycle in the central Mediterranean from new reflection profiles and well data from the accretionary prism and foreland to the Tyrrhenian Sea backarc.

1.1.3. Implications of Orogenic Cycles to Global Tectonics

Argnani (https://doi.org/10.1002/2017TC004632) presents a new paleotectonic model of the Dinarides with implications for the interpretation of the Cretaceous orogeny of the Eastern Alps and the nature and origin of the ophiolite belts exposed in eastern Europe.

Ballevre et al. (https://doi.org/10.1002/2017TC004633) present an analysis and interpretation of the role of pre-Alpine inheritance regarding rifting and later orogeny in the Alps.

Using new and published thermochronologic ages in the Central Alps, Price et al. (https://doi.org/10.1002/2017TC004619) have identified a mismatch in Cenozoic thermal histories in the Austroalpine allochthon and the Penninic substrate in the Central Alps. They propose that the overthrust of the Austroalpine and the Pennine zone was reactivated as a normal fault during the Oligo-Miocene with a minimum of 60 km of displacement. In contrast to the classical interpretation of the Alps, this implies that fault displacement mostly occurred late in the collision process, when the mechanical attachment of the subducted European crust to the downgoing plate was lost.

1.2. Part B: Cyclic Behavior in Other Global Orogens

1.2.1. Geologic Evidence Associated With Orogenic Cycles

Gavillot et al. (https://doi.org/10.1002/2017TC004668) used low-T thermochronology to determine late Cenozoic fault activity across the Kashmir Himalaya. The spatiotemporal evolution of deformation best fits a model where the underlying basal décollement has a ramp geometry and sub-Himalayan structures in the hinterland grew as a subcritical wedge.

Grobe et al. (https://doi.org/10.1002/2017TC004444) present and interpret evidence for deformation of the authochthonous carbonate sedimentary rocks beneath a part of the Semail ophiolite, Oman. They describe a variety of structural elements found in these sedimentary rocks, but the major focus is the character and geometry of overprinting arrays of mineral-filled veins and faults.

Hoy and Rosenbaum (https://doi.org/10.1002/2017TC004491) carried out a structural analysis of multiply deformed rocks from the eastern margin of Gondwana, yielding evidence for “pulses” of contractional deformation in the Permian and Triassic.

Iaccarino et al. (https://doi.org/10.1002/2017TC004566) used U-Pb geochronology of monazite, combined with field and microstructural studies, and other thermochronological methods, to provide new constraints on the Miocene timing and conditions of ductile shear on the South Tibetan Detachment System (STDS) in this area during progressive exhumation from P ~1.0 GPa and $T \geq 750$ °C to the brittle regime.

1.2.2. Geodynamic Processes Governing Orogenic Cycles

Fossen et al. (https://doi.org/10.1002/2017TC004743) compare the Araçuaí-West Congo and the Caledonian Orogens and, through both observations, and modeling demonstrate that temperature is the main factor controlling crustal rheology. This, in turn, affects the geometry and tectonic style of the belt and even the evolution of the collision zone.

Maffione et al. (https://doi.org/10.1002/2017TC004790) reconstruct the tectonic history and paleogeography of the Neo-Tethys Ocean closure from paleomagnetic analyses of dykes and existing geologic evidence in the eastern Mediterranean.

Mescua et al. (https://doi.org/10.1002/2017TC004626) consider the geodynamic processes that could have resulted in a widespread episode of upper plate contractional deformation that affected Costa Rica and Nicaragua in the Miocene. They conclude that this event relates to a change in convergence direction of the subducting Cocos plate rather than the attempted subduction of the Cocos Ridge as was the existing paradigm.

1.2.3. Implications of Orogenic Cycles to Global Tectonics

Horton et al. (https://doi.org/10.1002/2017TC004624) examined basin sedimentology, volcanism, and fault slip history in transects across the southern Andes, determining that variation between overall contractional and local extensional deformation is related to temporal variation in coupling on the subducting plate interface, possibly related to slab rollback.

Lister et al. (https://doi.org/10.1002/2017TC004708) present an analysis of earthquakes along the rupture zone of the 2004 great Sumatra earthquake. This article was spotlighted in EOS: https://eos.org/research-spotlights/evidence-for-gravity-tectonics-after-the-great-sumatra-quake.

Symeou et al. (https://doi.org/10.1002/2017TC004667) interpret two-dimensional seismic data to find three separate crustal domains south of the Cyprus Arc system that illustrate the deformation front migrated southward and peaked in the mid-late Miocene. Later, in the Plio-Pleistocene the western escape of Anatolia resulted in the reactivation of these existing structures.

We are pleased to present these advances in knowledge of orogenic cycles to the global scientific community and hope that Dr. Beltrando's indomitable spirit will touch the future research they inspire.

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